DOI: https://doi.org/10.56198/ZH3JOCS4L

Work-in-Progress—Game-Based Assessments for Programming

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Abstract. Concerns exist regarding the methods used to implement various assessment types and how they affect students' learning and participation. Assessments require a large amount of time to mark and to provide feedback to the student which comes after the task is completed and lacks interaction and engagement of students. Game-based learning has been known to enhance the interaction between learner and teacher and is useful in embedding interactive tasks. Game mechanics and principles can be used to develop Game-based assessments (GBAs) to assess a student's understanding of learning concepts enhancing the use of assessments in classroom settings, albeit GBA is still in its infancy. In order to incorporate assessment tasks for programming courses, this paper offers a basic prototype of how game mechanics, domain knowledge, pedagogy, and learning mechanisms can be linked to design GBAs to align with learning objectives.

Keywords: Game-Based learning, Assessments, Feedback, Programming Course, Student Interaction.

1 Introduction

Game-based learning (GBL) is a process of adapting some gaming principles to real-world situations in order to engage players [1] and is achieved by educational games with elements such as engagement and immediate rewards. GBL has gameplay with defined learning outcomes [2]. The motivational psychology involved in GBL allows students to engage with educational materials in a playful and dynamic way. GBL aims to improve participants' motivation, engagement, and learning outcomes through the inclusion of game elements and structures [3, 4].

Programming can be a challenging subject for novice programming students [5]. Innovative technologies such as GBL, Augmented Reality (AR), and Virtual reality (VR) can be employed to inculcate analytical and reasoning skills that are required to solve specific problems and achieve a basic level of understanding. These technologies can support writing complex programming concepts through features such as rich informational content and visualization. In a relevant study, authors reported that teaching sorting algorithms through VR simulation resulted in greater learners' engagement and interactivity with higher levels of flow and positive emotions [6]. Another study conducted with high school students demonstrated the potential of the 3-D VR environment in improving students' knowledge, comprehension, and application skills in teaching concepts in the computer science discipline [7]. AR is used as a valuable tool to write better-quality programs with fewer errors by supporting debugging tasks leading to enhanced feelings of satisfaction and enthusiasm in learners [8, 9].

Assessments are the focus of assessing students and educators have voiced worry about the disconnect between student evaluation and learning. Academic success is not only about getting high grades but also the accomplishment of the learning process and gaining subject knowledge, which results in achieving high grades [10]. The current learning needs of students from different backgrounds have forced the need for developing more

engaging assessments and feedback practices. Receiving high grades is not an activity but a result of continuous activities completed to achieve the result.

Designing assessments based on these tools can help create a more realistic assessment experience for learners and provide motivational and cognitive benefits [11]. GBA can be used to provide continuous activities to students helping them achieve their goals of learning. The process of using game thinking and game mechanics to solve problems and engage users [12] can be used to develop game-based assessments. This paper provides a rudimentary prototype of how game mechanics, domain knowledge, pedagogy, and learning mechanisms might be integrated in order to include evaluation tasks for programming courses. A review of the relevant literature is presented in Section 2, game mechanics and principles to design assessments are covered in Section 3, the research study design is in Section 4, and the study is concluded with suggestions for further research in Section 5.

2 Literature Review

There is a greater need for coherence among teaching, learning, and assessments for better interactive learning for students [13]. The old school of thought to provide standardized assessment tasks is dated now [14]. With the advancement of artificial intelligence (AI), virtual reality (VR), and augmented reality (AR), GBLs are providing a new platform for immersive learning to students [15] addressing the decline of student engagement and motivation [16].

Programming has a reputation for being one of the most difficult disciplines to master [17]. According to [18], a variety of factors, such as students' past knowledge and attitudes, teaching and learning strategies, and social context, might cause learning challenges in computer programming. They also stated that among the causes of bad performance in programming courses are students' lack of problem-solving abilities and mathematical background as well as programming questions put out there by lecturers that extend beyond the cognitive growth of the students.

GBAs aim to provide more engaging learning activities [19] by blurring the line between traditional assessments and allowing students to apply their knowledge in game-based real-world situations and experience it [20]. GBAs within GBLs can be used to engage participants in multiple domains; emotional, cognitive, behavioural, and social [1]. Numerous studies have noted the positive effects of the GBL environment on student motivation, engagement, and learning [12, 21]. GBAs provide cognitive outcomes in terms of knowledge gains allowing learners to practice their skills in a virtual environment. Randel et al. [22], in their study, have suggested that the use of a GBL environment is more beneficial than traditional classroom learning and that GBAs have the potential to decrease students' test anxiety and improve their exam performances [23]. However, GBAs must be designed very carefully to fit the purpose, otherwise, learners can get stuck in a state of confusion [24]. A promising direction is to replace programming teaching with animated visual explanations [25].

Students may demonstrate a lack of analytical problem-solving abilities by being unable to apply classroom examples to other fields with comparable situations. These issues for the students may result in bewilderment, a lack of self-assurance, and a lack of will to continue [26]. However, Mathrani et al. [27], have demonstrated that GBL brings fun to the classroom by engaging students, helping them learn programming skills, and allowing students to perceive programming to be interesting.

Digital technologies have transformed society, but assessment design may not have kept pace with the digital world. Educational technologies tend to reproduce established academic practices [28] and, while there are new means of implementation, such as GBAs, the fundamentals of assessment design appear to remain constant [29]. The so-called "death of distance" can be achieved by eliminating the requirement for students to be physically and chronologically synchronized with instruction through the use of digital technology, such as smartphones, tablets, and laptops, especially when they are connected to the internet [30]. Additionally, the COVID-19 pandemic has highlighted the need for a robust system of education that can be delivered remotely [31]. GBL is one that can be very helpful in delivering education online by reducing loneliness and boredom [32].

There is a number of existing game-based assessment design frameworks [12, 13, 15, 21, 22, 23, 27], However, the existing game-based assessment design focuses on problem-solving [33] where it is designed to assess a player's problem-solving abilities by presenting them with challenges or puzzles that require critical thinking and analytical skills and designed to assess a player's emotional intelligence [34] by presenting them with scenarios that require them to identify and manage their emotions, as well as those of other players. However, there is a little evidence of how game-based assessments can be designed for programming by evaluating a player's ability to write, debug, and optimize code after providing real time feedback. Game-based assessments for programming can be designed to evaluate a player's ability to write, debug, and optimize code, as well as their ability to collaborate and work effectively in a team and these abilities can be enhanced by providing real-time feedback.

GBL can foster the pedagogical field with a variety of approaches rather than as a single style of pedagogy [35]. Hattie and Timperley [36], have suggested that the three key self-reflective questions must be addressed through feedback in order for learning to take place. These feedback strategies are based on the ideas of where I'm going (feed-up), how I'm going (feed-back), and where to go from here (feed-forward). These three key points of feedback, feed-up, feed-back, and feed-forward help learners get engaged with the learning resources and motivate them to take responsibility for their own learning thus contributing to the theory of knowledge. Feed-up reflects on areas of improvement to identify successes and areas for growth. Feed-back is to provide /get regular feedback to gain insights into the performance and areas for improvement. Feed-forward is to use the feedback to develop an action plan for the future, identifying areas of focus and strategies to achieve the goals. Based on timing, feedback is divided into immediate feedback, instant feedback (after completing the assessment), and delayed feedback (feedback messages after a few minutes or longer) [19].

3 Principles to Design Assessments

GBA embedded in GBL will help support real-time feedback in a variety of ways. For example, by tracking the progress of learners, games can provide real-time feedback on their performance. By providing rewards and points for completing tasks, games can also encourage learners to receive feedback and adjust their strategies accordingly. Finally, interactive elements in games, such as quizzes and polls, can provide learners with immediate feedback on their understanding of a topic. GBA and GBL are both instructional approaches that use digital games or simulations to promote learning and can be used to assess a student's knowledge or skills. While they both involve the use of digital games or simulations, the goals of each approach are different. GBA is used to assess a student's knowledge or skills, while GBL is used to teach content [37]. GBA embedded in GBL will make teaching effective and motivating for learners.

Also, the difference between GBA and gamification needs to be understood to develop GBAs. Gamification is the addition of game-like elements to existing tasks or activities to increase engagement, flow, or motivation [38], albeit does not address pedagogy, where constructive alignment to learning needs is required. GBA is not a gamification where a leaderboard, badges, personalized avatars, or progress bars to classroom activities are added [39]. GBA requires a component of pedagogy and technology embedded into a game for the development of the constructive knowledge of students and this takes the form of serious games. Serious games are defined as games in which learning has priority over entertainment and is designed with a primary pedagogical goal [40]. Serious game design is a relatively new discipline that couples learning design with game features. Kenny and Gunter [41] make the case that learning game information can be closely tied to (and hence deeply immersed in) the game's narrative components.

The pedagogy relates to how content is taught, and refers to the strategy of how educators teach, in practice and theory [42], and how the adoption of GBL can support teachers in developing assessments [43]. Learning mechanics is about how people learn to develop skills and strategies necessary for effective learning and game mechanics are the rules and components that make up a game, such as how players interact with each other, the rules of the game, and the objective of the game. They are essential in determining how fun and engaging a game is and how well it will be received by players.

The principles to design GBAs require four components: pedagogy, learning mechanics, knowledge of domain experts, and game mechanics to align with the learning objectives as GBL requires teachers to cultivate a set of dynamic knowledge and skills called Technological Pedagogical Content Knowledge [44]. GBAs should also include the three bullet points of feedback as researched by Hattie & Timperley [36]; feed-up; feed-back; and feed-forward using game mechanics and principles. Game mechanics determine how to make the game entertaining and motivating, learning mechanics determine how learning should be prioritized in the design, pedagogy determines how the learning resources should be included in the game, and domain knowledge from experts is required to identify content that is embedded in GBAs. Figure 1 shows the four components to design GBAs to meet learning objectives.

The components required to design GBAs aim to harness the potential of GBL in higher education. The primary pedagogy for GBAs is to use knowledge from domain experts to identify the content that best suits the learning objectives [40]. Learning mechanics should be designed to create an engaging and interactive experience for the learners. These mechanics should be used to guide the learners through the assessment tasks in a way that encourages and rewards learning. Game design should be used to create an immersive environment that fosters and encourages learning and gives learners the opportunity to practice the skills they are being assessed on. Lastly, GBAs should focus on providing feedback to players on their progress and understanding of the content in order to ensure they are able to further develop their knowledge.

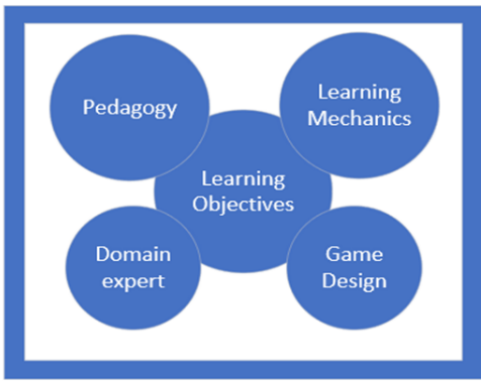

Fig. 1. Components to design game-based assessments.

4 Research Design

One important aspect to consider when designing GBAs is to ensure that it aligns with the desired learning outcomes. The game should be designed in a way that allows students to learn the required content while they are being assessed. For example, if the assessment is designed to evaluate a student's knowledge of a particular concept, the game should be designed to provide the student with an opportunity to practice and apply that concept. Questions and tasks should be included that requires the student to demonstrate their understanding of the concept in order to progress through the game.

Another important pedagogical aspect to consider when designing GBAs is to ensure that the game is engaging and motivating. It is important to create a game that is enjoyable and that encourages students to continue playing. The game should also be designed to provide feedback that is timely and meaningful. This can be accomplished by providing clear instructions, clear goals and objectives, and providing feedback that helps the student identify how they can improve their performance. Finally, it is important to ensure that the game-based assessment is accessible to all students. This can be accomplished by providing an easy-to-use interface, providing clear directions and instructions, and selecting game mechanics and visuals that are appropriate for the student population. The pedagogical principles and theories that the developed game is grounded are: Constructivism, a learning theory that suggests that learners construct knowledge by actively engaging with the world around them; and Gamification which is the use of game elements and mechanics in non-game contexts.

To incorporate pedagogical aspects in GBAs, a game has been designed that will be used to teach programming concepts to first-year university students. The game has been designed for first-year programming students studying at Australian Universities. This game will be deployed at three Australian Universities in the next term. The GBAs set clear expectations for game-based learning. A set of clear goals and objectives are provided at the beginning of the game with clear instructions and guidance on how to play the game. The proposed programming game represents the learning content and assessments based on three United Nations Sustainable Development Goals (UNSDGs): UNSDG1 No Poverty, UNSDG3 Health and Well-being, and UNSDG4 Quality Education [45].

This game is designed to incorporate immersive elements of virtual reality to create an engaging and interactive learning experience for the learner. The Gamification concept is used to create an immersive and engaging experience for the learner. The game has game elements such as points, badges, and leaderboards in the assessment to make it more immersive. The game developed also uses storytelling around UNSDGs to create an immersive experience that captures the learner's attention and motivates them to engage with the assessment. The game design has a narrative around the assessment that helps the learner connect with the subject matter. The player engages with a variety of characters within the game-based learning environment who instruct them on programming fundamentals using situations based on three UNSDGs. Three levels make up the game, which was created using the Unity game engine. Level 1 presents fundamental programming concepts such as data types, variables, and sequential programming as the player begins their investigation. By the time the player reaches level 2, they are exposed to more advanced programming ideas including conditions, loops, and arrays. At level 3, players are introduced to inheritance and other ideas from object-oriented programming. The player's learning is evaluated via assessment tasks, such as multiple-choice programming questions, at the conclusion of each level in accordance with Bloom's Cognitive Competency's learning taxonomy model [44]. Completing the assessment tasks at each level will allow the acquisition of the required knowledge and skills for subsequent goals.

GBAs can make the learning environment fun and can maintain optimal challenges for successful learning. The design of GBAs has been aimed to reduce the boredom and isolation students have while working on their

assessments and learning the concepts by implementing a good balance of game elements and psychological theories of curiosity and motivation. The game elements have been incorporated into the assessment such as points, levels, rewards, and leaderboards. This makes the assessment more engaging and enjoyable for students.

Kickmeier-Rust et al. [46] point out that the interaction of players with the learning platform through continuous feedback cycles can support the learner to achieve the required competency and enhance curiosity and motivation. In this game, feedback offered for each task through different channels such as audio, video, and text, promotes feelings of autonomy and competence that are considered to be significant aspects of enhancing motivation [47]. Additionally, different types of feedback presented in the game for incorrect answers support the concepts of feed-up (where am I going); feed-back (how am I going); and feed-forward (where to next), as suggested by Hattie & Timperley [36]. The prototype of the developed game uses adaptive learning which allows the learner to adjust the difficulty of the game or assessment based on the learner's performance. This helps learners focus on topics they need to work on while still being challenged. Assessments and feedback are closely intertwined. Assessments are used to measure a student's understanding of a topic and to provide feedback to the student on what they need to improve. This feedback can be used to develop a plan to help a student better understand the material, as well as to give the student an idea of how their work is being evaluated.

To enhance the learning experience and GBAs outcomes, it is important to couple key game elements with learning mechanics rather than focus purely on the entertainment aspect of the game [48]. Using this approach, a variety of programming questions have been created to be included in GBAs and interlinked with game elements for balancing learning with play. Designing game-based learning and GBAs is a multidisciplinary work that involves the integration of knowledge from different domain experts [49]. Domain experts were invited to join the development team and provide their expertise throughout the entire process. All members collaborated and shared their knowledge from the initial stage and participated in the iterative process of designing the game environment, assessment questions, and suitable characters to display while playing the game. The following are the steps that were carried out during the development of the GBA:

- Domain experts were asked to provide input on the GBA content, such as what topics should be covered, and which activities should be included.
- Domain experts were invited to review the GBA questions and provide feedback.
- Domain experts were invited to beta test the GBA and provide feedback on the difficulty level and the overall design of the game.

The following figures display snapshots of the prototype game that has been developed. (see Fig. 2) for GBA implementation.

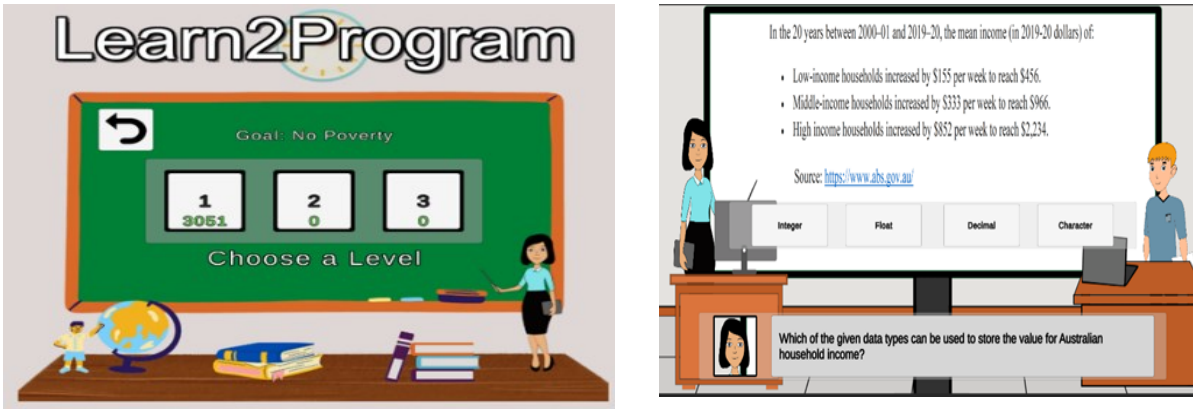

Fig. 2. The programming game snapshot 1.

5 Conclusion and Future work

This paper reports on the four components: pedagogy, domain experts, learning mechanics, and game design to design game-based assessments to achieve learning objectives. A prototype is designed on the Unity game engine to provide insight into the feasibility of implementing GBA in the classroom. The research discussed in this paper provides a stepping-stone for further research and development in the field of GBAs. This game-based assessments for programming will be used in computer science courses to evaluate students' understanding of programming concepts and their ability to write code. They can also be used by employers to assess job candidates'

programming skills and competencies. Future research will focus on the further development of the prototype and on further refinement of the GBA system. Further research will also focus on assessing the effects of GBA on student learning outcomes and engagement. The identified principles will support educators and game developers conceptualizing GBA by providing guidance to use the game mechanics and utilizing assessment strategies, which helps them conceptualize the learning activities and gives them a good foundation for considering how it might be implemented in higher education.

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